
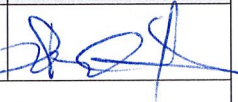



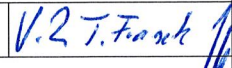



<b>Confidentiality Level</b>	<i>BL - Restricted for internal use</i>	<b>TC ID / Revision</b>	00338060/C
<b>Document Status</b>	<i>Document Released</i>	<b>Document No.</b>	N/A
<b>WBS code</b>	<i>3.1 - L1 System</i>		
<b>PBS code</b>	<i>RA1.L1.L1_2.BT.DM</i>		
<b>Project branch</b>	<i>Engineering &amp; Scientific documents (E&amp;S)</i>		
<b>Document Type</b>	<i>Specification (SP)</i>		
<p><b>[RSD product category C]</b></p> <p><b>Deformable mirror for FSYNC</b></p> <p><b>TP22_016</b></p>  <p><b>Keywords</b></p> <p>N/A</p>			
	<b>Position</b>	<b>Name</b>	
<b>Responsible person</b>	Group Leader of L1 Allegra Laser	Pavel Bakule	
<b>Prepared by</b>	Scientist	Jakub Novák	



<i>RSS TC ID/revision</i>	<i>RSS - Date of Creation</i>	<i>RSS - Date of Last Modification</i>	<i>Systems Engineer</i>
024269/A.001	29.07.2022	29.07.2022	A. Kuzmenko
024269/A.002	02.08.2022	02.08.2022	A. Kuzmenko
024269/A.002	09.08.2022	09.08.2022	A. Kuzmenko

<b>Reviewed By</b>			
<i>Name (Reviewer)</i>	<i>Position</i>	<i>Date</i>	<i>Signature</i>
Daniel Kramer	Group leader of Optical Materials Development	09.08.2022	
Jack Alexander Naylor	Group leader of Laser Control Systems	via TC	
Pavel Bakule	Deputy of Head of Department	09.08.2022	
Petr Strkula	Designer	10.8.2022	
Radek Toman	Legal Group Leader	9.8.2022	
Roman Kuřátko	Head of Department of Building Infrastructure and IT	NOTICE	
Veronika Olšovcová	Group Leader of Safety	9.8.22	
Viktor Fedosov	Group Leader of Quality and Planning	via TC	

<b>Approved by</b>			
<i>Name (Approver)</i>	<i>Position</i>	<i>Date</i>	<i>Signature</i>
Bedřich Rus	Head of department of Laser Systems	10/8/2022	

<b>Revision History / Change Log</b>				
<i>Change No.</i>	<i>Made by</i>	<i>Date</i>	<i>Change description, Pages, Chapters</i>	<i>TC rev.</i>
1	J. Novák	27.07.2022	RSD draft	A
2	J. Novák, A. Kuzmenko	02.08.2022	RSD update; version for review	B
3	A. Kuzmenko	09.08.2022	RSD update; final version	C

## Table of Content

1. Introduction .....	4
1.1. Purpose .....	4
1.2. Scope .....	4
1.3. Terms, Definitions and Abbreviations .....	4
1.4. References to Standards .....	5
2. Functional, Performance and Design requirements .....	5
3. Environmental requirements .....	8
4. Delivery requirements .....	8
5. Safety requirements .....	9
5.1. General Safety Requirements .....	9
5.2. Machine Safety Requirements .....	9
6. Quality control .....	9
6.1. Factory test reports .....	9
6.2. Documentation and data control .....	10
7. Verification Requirements for the Supplier .....	11
7.1. General Requirements .....	11
7.2. Verification Control Document (VCD) .....	12
7.3. Phasing of the delivery .....	12
7.3.1. Qualification of Design .....	13
7.3.2. Manufacturing .....	13
7.3.3. Acceptance .....	14



## 1. Introduction

### 1.1. Purpose

This Requirements Specification Document (RSD) lists the technical requirements and constraints on a deformable mirror for the L1\_2 beamline under the ADONIS FSYNC project.

### 1.2. Scope

This RSD contains functional, performance and design, delivery, safety, and quality requirements for the following product (Tender number TP22\_016): **Deformable mirror for FSYNC** for use in the L1 laser.

The deformable mirror (DM) will be used for matching wavefronts of L1.1 (after the fourth OPCPA stage) and L1.2 output for efficient coherent combination. This DM is registered in the PBS database under the following PBS code: *RA1.L1.L1\_2.BT.DM*.

The DM shall operate on air with a Gaussian beam with pulses with energy of up to 15 mJ, 1 kHz repetition rate, pulse duration of 3 ps and bandwidth between 740 – 950 nm. The angle of incidence (AOI) shall be 45°. The DM shall not lose its setting when it is powered off. As part of the delivery shall be also one spare mirror membrane with identical parameters as the one in the DM adjusted for a direct replacement. Detailed information on the beam and mirror performance and the spare membrane are given in Chapter 2.

### 1.3. Terms, Definitions and Abbreviations

For the purpose of this document, the following abbreviated terms are applied:

Abbreviation	Meaning
A	Analysis (as verification methods)
AAp	Active Aperture of the deformable mirror
AOI	Angle of the Incidence
CA	Contracting Authority (Institute of Physics CAS)
DM	Deformable mirror
ELI	Extreme Light Infrastructure
FTR	Factory Test Report
GDD	Group Delay Dispersion
I	Inspection (as verification method)
LIDT	Laser Induce Damage Threshold
NCR	Nonconformity Report
OASys	Commercial adaptive optics software produced by Phasics
R	Review (as verification methods)
RA1	Research Activity 1
RSD	Requirements Specification Document
SDK	Software Development Kit
T	Test (as verification methods)
VCD	Verification Control Document



## 1.4. References to Standards

If this document includes references to standards or standardized/ standardizing technical documents the CA allows/permits also another equivalent solution to be offered.

## 2. Functional, Performance and Design requirements

Functional, performance and design requirements for the Deformable mirror (DM) for FSYNC and procedures for FTR to be performed are described in this document below.

REQ-034812/A

The Supplier shall supply **one DM system** and **one spare mirror membrane** according to the specifications below.

---

Verification method: I - inspection

REQ-034813/A

The DM shall be able to fulfill all the requirements from this chapter with the **laser beam with parameters** listed in Table 1 below.

---

Verification method: R - review, T - test

REQ-034814/A

**Angle of incidence** of the DM shall be 45 deg. The mirror membrane dimensions and the distribution of actuators shall be accommodated to this AOI.

---

Verification method: R - review, I - inspection

REQ-034815/A

The DM **parameters** shall correspond to Table 2 below.

---

Verification method: R - review, T - test, I - inspection

REQ-034816/A

The spare membrane shall have an identical coating and physical properties as the membrane used in the DM and it shall fulfill the same requirements according to table 2 when installed in the DM.

---

Verification method: R - review, T - test, I - inspection

REQ-034817/A

The Supplier shall provide as part of the bid the calculated design performance of the mirror coating demonstrating reflectance and dispersion at the given operational wavelength range of the mirror installed in the DM and the spare membrane (see Table 2).

---

Verification method: A - analysis, R - review (as part of bid evaluation)

REQ-034818/A

Part of the delivery shall be a 19" Control Rack integrating controllers for all actuators and providing communication to an external PC (provided by the CA) via an Ethernet interface.

*NOTE: Other interface types are not acceptable.*

---

Verification method: R – review (as part of bid evaluation), I – inspection

REQ-034819/A

The Control Rack shall be fully compatible with the OASys adaptive optics control software (provided by the CA). The Control Rack shall also be controllable using custom software (developed by the CA), communicating directly with the Control Rack over Ethernet via a simple command set. A Windows 10, which the CA already has and uses, compatible SDK and full documentation of the command set shall be provided.

---

Verification method: R – review (as part of bid evaluation), T - test

REQ-034820/A

The Control Rack shall be provided with a simple HTTP web server with which to check the basic status of the device and to view and configure the IP address settings of the main control interface. Via this web interface, it shall be possible to configure the Control Rack to have any valid, fixed IPv4 address, subnet mask and gateway, as required.

---

Verification method: R – review (as part of bid evaluation), T - test

Parameter	Specified value
Central wavelength	850 nm
Bandwidth	740 nm - 950 nm
Repetition rate	1 kHz
Beam polarization	Vertical, S-pol
Beam shape	Gaussian
Pulse energy	15 mJ or less
Pulse duration	3 ps
Beam size	Compatible with 2" optics; can be adjusted after agreement with the CA
Environment	Air

**Table 1:** L1.2 laser parameters at the DM location



#	Parameter	Specified value	Comment/Note
1	Clear aperture where coated membrane shall meet all specifications	$\varnothing 60 \times 42 \text{ mm}^2$	Can be smaller if performance of the DM meets all the requirements
2	Active aperture (AAp) where actuator pattern shall be optimized	$\varnothing 42 \times 30 \text{ mm}^2$	Can be smaller if performance of the DM meets all the requirements
3	Minimal amount of actuators	35	To be optimized for the Gaussian beam footprint on the AAp mirror surface
4	Coating	Dielectric or enhanced Ag (Ag + dielectric)	
5	Minimal bandwidth	740 – 950 nm	
6	Reflectivity S-pol / P-pol	> 99.5 %	Over the specified bandwidth
7	LIDT	> 0.2 J/cm <sup>2</sup>	10000-on-1 t < 3 ps
8	GDD	-50 fs <sup>2</sup> < GDD < 50 fs <sup>2</sup>	Over the specified bandwidth
9	Maximum power-off change	<10 nm RMS over 1h	Surface shape to be identical to the powered state. Temperature drift subtracted
10	Actuator pattern	Optimized for the first 14 Zernike polynomials	Simulation results to be provided by the Supplier and discussed with CA before the start of manufacturing
11	Baseline surface sag (flattening)	Flat with RMS $\leq 10 \text{ nm}$	Over AAp
12	Correction range for 45 deg astigmatism	$\geq \pm 15 \mu\text{m}$	Relative residual to flat sag <25 nm RMS
13	Correction range for horizontal and vertical defocus	$\geq \pm 15 \mu\text{m}$	Relative residual to flat sag <25 nm RMS
14	Correction range for coma	$\geq 5 \mu\text{m}$	Relative residual to flat sag <25 nm RMS
15	Capability to tailor the focal spot intensity distribution	Any desired shape compatible with REQ # 10, 11, 12, 13 and 14	
16	Tip / tilt adjustment	mechanical	
17	Length of cables to a control unit	$\geq 5 \text{ m}$	
18	Beam height	100 mm	Measured from the table to the center of the AAp
19	Position of the connectors	Back or side plane	To be agreed with CA

**Table 2:** Specifications and requirements for the DM

### 3. Environmental requirements

REQ-034821/A

The Supplier and the CA shall agree on the cleaning method to clean the DM without decreasing the DM's properties and to avoid contamination of the clean space.

*NOTE: The cleaning methods may use high gas flow (dry air) and specialized chemical cleaning liquids (i.e. methanol, isopropyl alcohol, deionized water).*

---

Verification method: R – review

REQ-034822/A

The DM shall satisfy the parameters given in Table 2 at the temperature of 20 deg. C and maintain them within the temperature range of  $\pm 1$  deg. C.

---

Verification method: T - test

### 4. Delivery requirements

REQ-034823/A

The packaging and transportation of all the components to the CA site at Dolní Břežany shall be conducted by the Supplier.

*NOTE 1: The Supplier is fully responsible for the delivery of the undamaged DM.*

*NOTE 2: The bid price will be considered by the CA as the final price, including transportation cost.*

*NOTE 3: The DM will be installed by the CA. The Supplier will provide all necessary documentation detailing procedures for safe and proper installation and, if required, technical remote support and consultation.*

---

Verification method: I – inspection

REQ-034824/A

All the components of the delivery shall be cleaned and packaged in the clean environment of class 7 according to ČSN EN ISO 14644 (equivalent to EN ISO 14644) or cleaner.

---

Verification method: I – inspection



## 5. Safety requirements

### 5.1. General Safety Requirements

REQ-034825/A

The Supplier shall supply a Declaration of Conformity (DoC) for each product type. The DoC shall declare compliance in part with:

- Act No. 176/2008 Coll., as amended (2006/42/EC);
- Act No. 118/2016 Coll., as amended (2014/35/EU);
- Act No. 117/2016 Coll., as amended (2014/30/EU);
- the other relevant EU/EC regulation and ISO standards.

Compliance with these obligations shall be demonstrated by the (EU/EC) DoC and the CE/CCZ marking.

---

Verification method: I – inspection

### 5.2. Machine Safety Requirements

REQ-034826/A

The DM shall have internal detection and protection against, or be inherently resistant to sustaining damage from the following modes:

1. Sudden loss of external power on any supply;
2. Sudden loss of any external control signal or interface;
3. Overvoltage or overcurrent of internal power supplies;
4. Short-circuit or disconnection of any actuator output.

---

Verification method: R – review

## 6. Quality control

### 6.1. Factory test reports

REQ-034827/A

The Supplier shall perform tests of the **DM system and the spare membrane** and provide corresponding factory test reports (I - V):

- I. Measured reflectivity curve over the bandwidth specified in table 2 at s and p polarization;
- II. LIDT report of the same coating type on the same substrate material by the same coating supplier.
- III. Interferometric or high-resolution wavefront measurement of clear aperture after flattening normal to the surface. Use angle interferometry has to be discussed with CA if required by the coating. If stitching is needed, a procedure must be approved by the CA. The minimum resolution is 1 mm of the full usable aperture of table 2.
- IV. Table summarizing RMS residuals and RMS slope errors of first 21 Zernike polynomials;

- V. Measured GDD curve over the bandwidth specified in table 2 at s and p polarization.

---

Verification method: R – review

## 6.2. Documentation and data control

REQ-034828/A

The Supplier shall supply the following relevant manufacturing documents:

- **Full technical documentation** and **factory test reports** (see chapters 6.1 and 6.5.1), including raw data where available;
- storage, cleaning, operation and maintenance instructions;
- description of cable wires or connector pins;
- user manual for the software /communication protocols.

*NOTE: The scope of this documentation shall be agreed with the CA.*

---

Verification method: I – inspection

REQ-034829/A

The Supplier shall use the following data formats:

- \*.dat (Zygo binary file format for interferograms)
- \*.JPG, \*.PDF/A, \*.HTML, \*.ppt, \*.pptx
- CAD 2D: \*.dwg
- CAD 3D: \*.stp; \*.ste; \*.step or other 3D CAD formats agreed with the CA
- text processors \*.doc, \*.docx, OpenDocument Format
- spreadsheet processors \*.xls, \*.xlsx, OpenDocument Format

---

Verification method: Not To Be Tracked within VCD

REQ-034830/A

The Supplier shall establish and maintain a nonconformity control system compatible with ČSN EN ISO 9001 (equivalent to EN ISO 9001).

---

Verification method: Not To Be Tracked within VCD



## 7. Verification Requirements for the Supplier

The verification process will be performed by the Supplier to demonstrate that the **DM system** meets the specified requirements of the CA.

### 7.1. General Requirements

REQ-034831/A

The Supplier shall assign clear responsibility for the implementation of the verification process including the following activities:

1. **Verification planning** (via VCD, see chapter 7.2);
2. **Verification execution and reporting** (chapter 7.3);
3. **Verification control and close-out** (chapters 7.2 and 7.3.3).

---

Verification method: Not To Be Tracked within VCD

REQ-034832/A

Verification shall be accomplished by the Supplier through one or more of the following verification methods:

1. **Review**; Verification via Review (**R**) shall consist of using approved records (i.e. design documents and reports, technical descriptions, engineering drawings, manuals and accompanying operation documentation) or evidence unambiguously showing that the requirement has been met.
2. **Inspection**; Verification via Inspection (**I**) shall consist of visual determination of physical characteristics including photographs taken by the Supplier and sent to the CA proving that the specific requirements have been met.
3. **Test** (including **functional demonstration**); Verification via Test (**T**) shall consist of measuring product performance and functions under realistic operating conditions. When the test objectives include the demonstration of qualitative operational performance (functional demonstration), the execution shall be observed and results recorded.
4. **Analysis**; Verification via Analysis (**A**) shall consist of performing theoretical or empirical evaluations (e.g. mathematical models, calculations, etc.).

---

Verification method: Not To Be Tracked within VCD

REQ-034833/A

The results of the analysis shall be documented in the corresponding Analysis or Simulation Report and tracked in the VCD (chapter 7.2).

*NOTE: The content of the report shall be agreed with CA.*

---

Verification method: R – review



REQ-034834/A

The results of the test and functional demonstration shall be documented in the corresponding FTRs (see chapter 6.1) and tracked in the VCD (see chapter 7.2).

*NOTE: The analysis of data derived from testing shall be an integral part of the test and the results included in the test report.*

---

Verification method: R – review

REQ-034835/A

The results of review and inspection shall be tracked in the VCD.

---

Verification method: R – review

## 7.2. Verification Control Document (VCD)

The **VCD** is a living document which shall be used throughout the entire Contract delivery and its phases (see chapter 7.3 Phasing of the delivery). The **VCD** provides traceability during delivery phases (Qualification of Design, Manufacturing, Acceptance, etc.). The **VCD** represents a formal tool of communication between the Supplier and the CA (formal record, reporting tool).

The **VCD** will be provided by the CA and it can be accommodated to the Supplier's needs.

REQ-034836/A

The Supplier shall provide a Verification Control Document (VCD) for the reviews as agreed with the CA.

*NOTE 1: The CA can provide the Guidelines for the VCD preparation.*

*NOTE 2: The form of the VCD will be agreed between the CA and the Supplier based on the best commercial praxis used by the Supplier.*

*NOTE3: The VCD specifies **HOW** and **WHEN** each requirement is planned to be verified, when it was actually verified.*

---

Verification method: R – review

## 7.3. Phasing of the delivery

This chapter is intended to briefly summarize the basic milestones of the contract delivery. These milestones represent gates (checkpoints) where the quality of the delivery shall be evaluated.

Delivery shall not proceed past these gates unless their satisfactory accomplishment is approved by the CA.

Delivery lifecycle shall contain at least the following phases (quality gates):

- **Qualification of Design;**
- **Manufacturing;**
- **Acceptance.**



### 7.3.1. Qualification of Design

Summary of what has to be provided by the Supplier in terms of documentation (calculated design performance, manufacturing drawings, layouts and system's interface, etc.) before starting the manufacturing. The goal is to verify the **manufacturing drawings and design supporting documentation**.

The output of this phase is **Qualified Design**.

REQ-034837/A

Before the ending of the Qualified Design phase the Supplier shall provide the structure and content of FTRs (see chapter 6.1) and the content of the VCD ready to be implemented (see chapter 7.2).

---

Verification method: R – review

REQ-034838/A

Before the ending of the Qualified Design phase the Supplier and the CA shall agree on:

- final manufacturing drawings provided by the Supplier (see REQ-034828/A);
- exact layout of the actuators based on the Supplier's analysis (see **Table 2, item 10**);
- detailed procedures related to the testing during the manufacturing phase.

---

Verification method: R – review

### 7.3.2. Manufacturing

The goal is to demonstrate that the manufactured DM system meets the specified technical requirements (RSD) of the CA.

This quality gate concerns primarily:

- **Inspection of manufactured and assembled product;**
- **Testing at the Supplier's site (factory testing);**
- **Cleaning and Packaging;**

The output of this phase is the **Verified Final Product**.

REQ-034839/A

The results of the Manufacturing phase of verification shall be recorded by the Supplier in the corresponding **FTRs** (or in other test reports, if not specified in chapter 6.1) and provided to the CA for approval.

*NOTE1: The approval will be given if all the relevant requirements are met.*

*NOTE2: The results of all the tests shall be given strictly in units which are used to define the requirements in chapter 2.*

---

Verification method: R – review

REQ-034840/A

The final issue of the VCD shall be submitted to the CA after the approval of the last report and before starting the Acceptance phase (see chapter 7.3.3).

---

Verification method: R – review

### 7.3.3. Acceptance

The Acceptance phase shall demonstrate the following:

- Final delivered and installed **DM system** has been successfully verified and this process has been documented in an appropriate way through FTR and VCD (see chapters 6.1 and 7.2);
- All detected nonconformities have been solved in accordance with REQ-034830/A;
- Final **DM system** and **spare membrane** are free of fabrication errors.

In case of a successful acceptance phase, the CA will provide the Supplier with a signed acceptance protocol. In case of an unsuccessful acceptance stage, the CA shall provide to the Supplier the Nonconformity Report (NCR) and the process in accordance with REQ-034830/A shall be applied.

REQ-034841/A

The verification process shall be carried out by the Supplier and it is successfully completed when the final **DM system** complies with all specifications and the results of this process are documented in an appropriate way through the FTRs and VCD (chapters 6.1 and 7.2).

*NOTE1: Acceptance will be carried out by the CA (or if required, representatives/contractors appointed by the CA) on the final delivered and at ELI installed **DM system**.*

*NOTE2: In the acceptance phase, the final verification of the **DM system** and required documentation will be carried out by the CA within 4 weeks after the issuing of the latest Handover/takeover protocol.*

---

Verification method: Not To Be Tracked within VCD